The Science of **Garden**

Science around us series, booklet - V

The Science of GARDEN

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The Science of Garden

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FOREWORD

The young mind is ever inquisitive, sometimes they ask questions which is difficult to find within the limitation of the text books. This series deal with such questions emerging out of the garden and kitchen and other places; describe the amazing achievements in the field of S&T communication; describes the alternatives to the danger of chemicals that we use daily.

National Council for Science and Technology Communication (NCSTC) is an apex body set up with the objectives of communicating science and technology, stimulating scientific temper and developing scientific capability amongst the people has collaborated with Development Research Communication and Services Centre (DRCSC), Kolkata, which is devoted to spreading and popularizing environment science amongst people for last 25 years to bring out this series to demystify scientific phenomenon of science in daily life for the children. Hope the grown up will enjoy it too.

We trust that this will encourage the children to search for larger picture, dig deep in to the mysteries of science & successes of technology and of course sustainable living alternatives.

Dr. D.K. Pandey
Scientist 'E'

Nani wakes up early every Sunday, keeping herself busy in the backyard garden, planting trees, nurturing them, talking to them, as if they were her grand children!

Ramu ran out from the room – "What are you doing there Nani?"

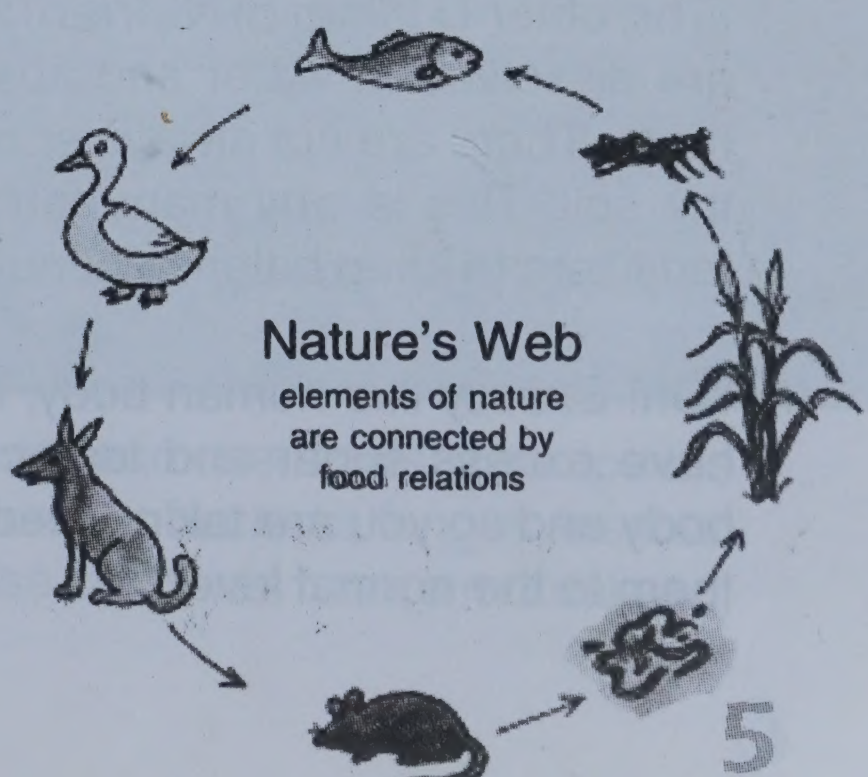
"Planting some saplings of lime plants, beta" – Nani replied.

"Oh! Really! When will they start giving fruits?"

"Well, it depends. Should not take more than six months, I think, provided they get proper nursing, nutrients, light and water."

'Nani, why are you planting them on a line with equal gaps? In the forest there is no such gap."

"That is where the garden is different from a forest. Garden is designed by human needs and forest is designed by the necessity of nature's web."

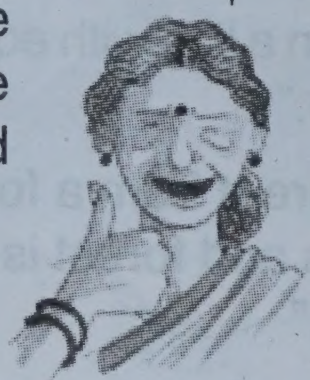


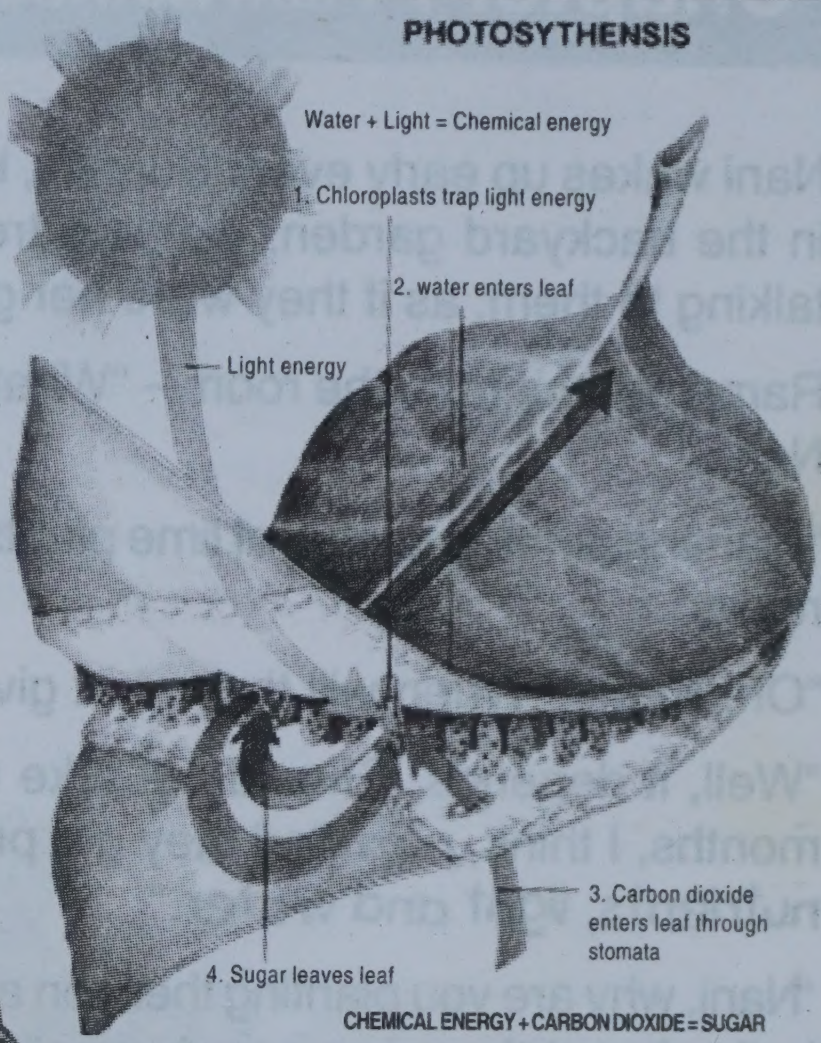
Nature's Web

elements of nature are connected by food relations

"Then, what is the most important thing that makes a garden good?"

"Well, it is not one component that helps a plant grow healthy. But you can say **soil** and **nutrients** are very vital factors. Different plants need different nutrients and different soil for their survival and growth. These nutrients are found in the **air**, water and soil."




PHOTOSYTHENSIS
Water + Light = Chemical energy
1. Chloroplasts trap light energy
2. water enters leaf
Light energy
3. Carbon dioxide enters leaf through stomata
4. Sugar leaves leaf
CHEMICAL ENERGY + CARBON DIOXIDE = SUGAR

The **Non-Mineral Nutrients** are **hydrogen (H), oxygen (O) and carbon (C)** that are found in the air and water. In a process called **photosynthesis**, plants use energy from the sun to change carbon dioxide and water into food.

"The other **13 Mineral Nutrients** that come from the soil are dissolved in water and absorbed through a plant's roots. There are not always enough of these nutrients in the soil. This is why many farmers and gardeners use fertilizers to keep balance of nutrients in the soil."

"Oh! Exactly like human body, right Nani? You have excess sugar and less calcium in your body and so you are taking medicines to bring them to the normal level."

There are lots of other minerals which are required for the healthy plants. The mineral nutrients are divided into two groups: **macro (large) nutrients and micro (small) nutrients.**

Among **Macro nutrients, Nitrogen (N), Phosphorus (P), Potassium (K)** are major nutrients These are not abundant in the soil as plants use large amounts for their growth and survival. The nutrients **calcium (Ca), magnesium (Mg), and sulphur (S)** are usually enough in the soil. Hece no substitution is required.

The micronutrients are **boron (B), copper (Cu), iron (Fe), chlorine (Cl), manganese (Mn), molybdenum (Mo) and Zinc (Zn)**. Recycling organic matter such as grass clippings and tree leaves is an excellent way of providing micronutrients to growing plants.

"You are absolutely right!" Nani appreciated.

"Now I understand, why we put fertilizer around the base of a plant." Ramu said. "Nani! How come a plant looks healthy in one field and pale and not so healthy in another?"

"I appreciate your observation Ramu. Yes! There is a scientific reason behind this difference. It again depends on the quality of the soil. Soil is not only a mixture of dead chemicals; it comprises of innumerable little creatures....bacteria, fungus, insects, worms, rodents etc. These creatures have a mutual and,

However, it has to kept in mind that chemical fertilizers harmfully affect the environment. Over-application of chemical fertilizers, or application of chemical fertilizers at a time when the ground is waterlogged or the crop is not able to use the chemicals, can lead to surface runoff or leaching into groundwater.

at times, even competetive relation, forming a food web incorporating the soil itself. If this web gets damaged, the balance of the soil also will be disturbed." - Nani answered patiently.

"Oh! That means we have to keep the soil alive. How to do that Nani?"

"There are many processes and techniques to keep the soil alive."

Ramu asked, "What are those?"

"One technique is mulching by straw, grass, dry leaves, rice husk, wood dust or even stones. Using leguminous creeper crops like Horse Gram, Grass Pea, Mung Bean etc. Leguminous crops are a good source of nitrogen to the soil."

"Why mulching is so effective? "

"Oh! The reason is very simple. The garden soil should be covered to protect it from sunlight, rainwater, air, damages done by man and animal and to retain the moisture and maintain the temperature, especially in dry, draught prone areas."

"Then how to maintain fertile soil for healthy gardening?"

"There are a few very simple methods."

Intermolecular space of a healthy and fertile soil is filled with water and air. These spaces help roots to respire, and water to move up and down. So the soil should be kept granular and loose as much as possible.

Rotating deep rooted and short rooted plant gives soil enough time to prepare itself for the next season, as pressure is less on a particular layer. Cereals and grasses are usually of short rooted. Leguminous crops like Cowpea, Pea, Cluster Bean, Pigeon Pea etc are deep rooted.

Use organic manure such as animal dropping and garden compost into the soil to create and recreate natural nutrients in soil by enriching web of micro-organisms in it.

Source of Nitrogen for composting and green manuring: urine and excreta of animals and birds, feather, skin of oil seeds, young leaves especially of Gliricidia, Subabul, Seaban, Indian Coal Tree etc.

Source of Carbon for composting: Straw, Coconut Fiber, dry leaves, cotton & jute waste, rice husk etc.

For loosening up soil, especially for clayey soil: Stone dust, rice husk, charcoal etc.

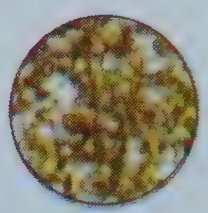
Moving water in a plant

Transpiration

'But, how do plant takes food Nani?' – Ramu was confused!

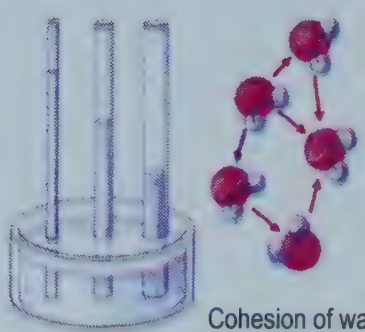
Plants intake food mainly with the help of two conducting tissues which are Xylem and Phloem. Xylem helps in conduction of water and dissolved minerals. Food is produced in the leaves, the produced food is then transferred to different plant organs through Phloem.

Transpiration
Water always travels from wet to dy regions. Since air is drier than a leaf, water evaporates from the leaf through its stomata into the air. This creates a water tension between the leaves and the roots that draws water up through the Xylem.



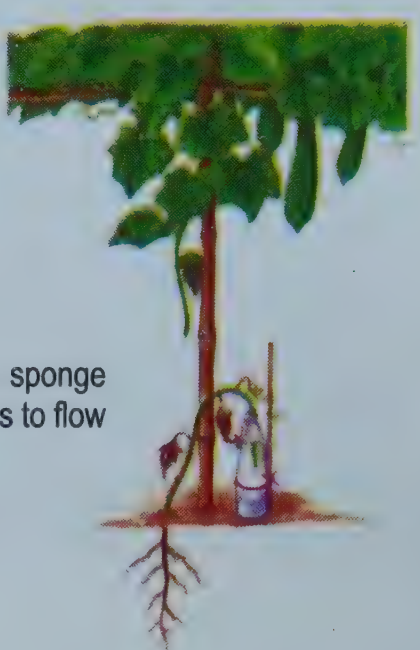
Stomas

Cohesion
Water is able to climb hundreds of feet in a tree because water molecules stick to each other and to the walls of the Xylem tubes. This phenomenon is called cohesion. Cohesion increases as the diameter of the tube decreases.



Cohesion of water

Root pressure
Root tissue absorbs more and more water and minerals as it grows. As water in the roots increases, pressure builds up, forcing water into the Xylem and up into the stem.



Even after the stem of a sponge gourd is cut, water continues to flow upwards from the roots.

Do it yourself

Production of Vermicompost

About earthworms

Earthworms like to live in moist, cool, dark places. Earthworms have no ear or eyes, but they have sense of vibrations & light and dislike both. They like vegetable peels, tree leaves, tea leaves, fruit pulp, torn paper, & cardboard etc. They dislike meat, fish, milk products as well as oils & fats etc.

How to raise?

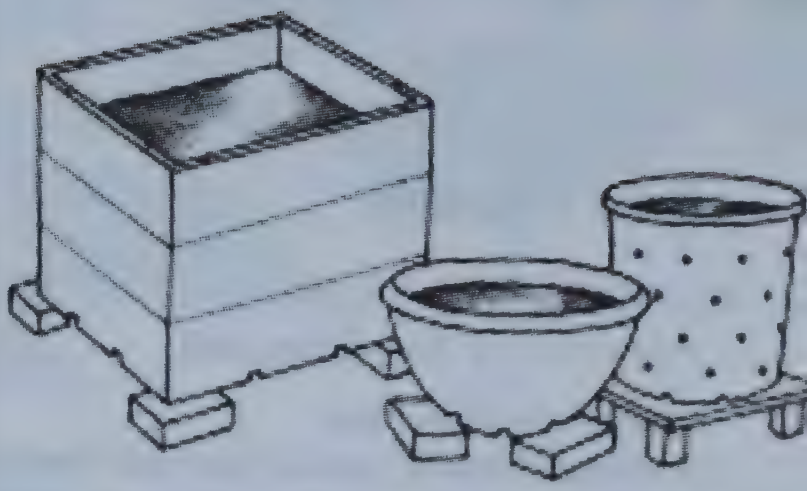
Step 1 : take a old packing box, drill 12-15 drainage holes of 6 to 8 mm diameter at the bottom at about 15 cm interval.

Step 2 : lay 4-5 sheets of newspaper over the holes & fill with small pebbles upto 3 finger depth (5-6 cm), wash the pebbles well before putting them in the box.

Step 3 : cover the pebble bed with 3-5 cm depth layer of soil.

Step 4 : build up a 15-20 cm deep layer of crumbled paper, coir or torn up cardboard / corrogated paper. These materials should be soaked for 2-3 hours or longer in water & squeezed well before being put in the box. Add the earthworms inbetween the wet layers.

Step 5 : add a 30-35 cm deep layer of straw and dry leaf which has been cut into small pieces. Food scraps will be buried 5-6 cm deep into this layer everyday.



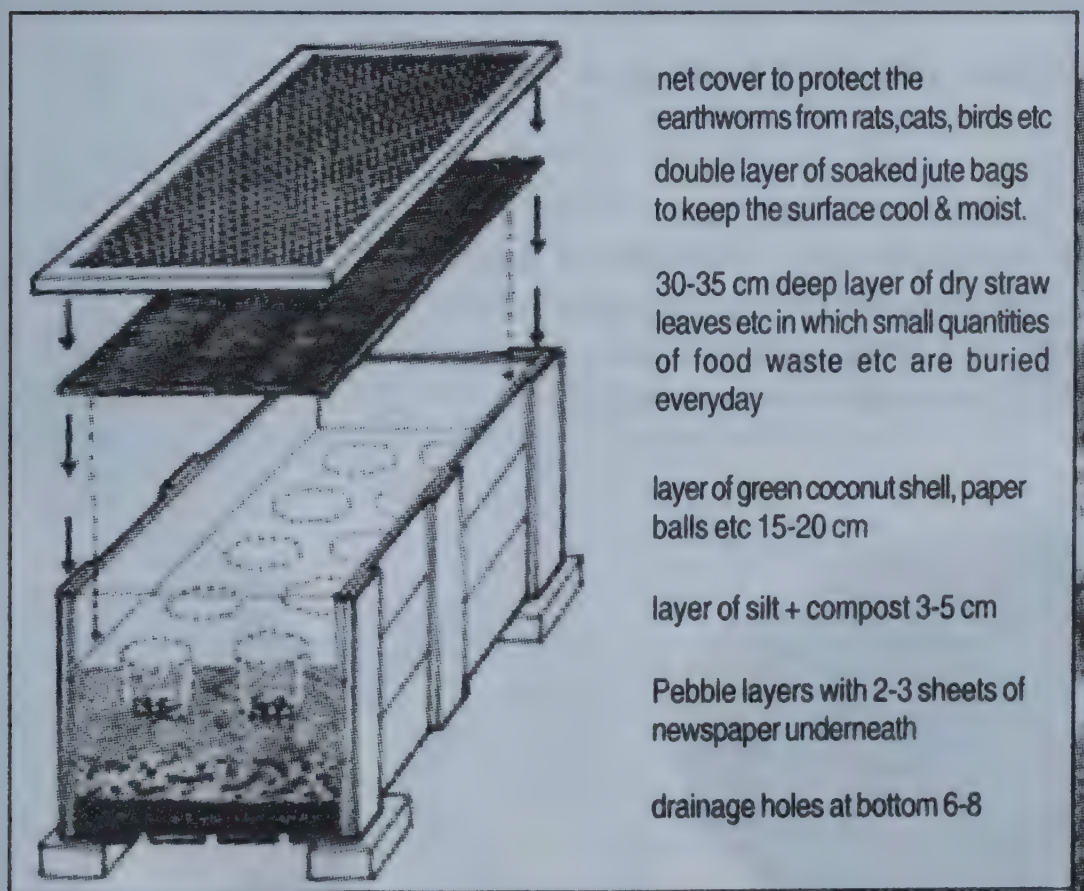
Step 6 : cover up the top with a double layer of wet jute / cloth or gunny bag.

Maintenance : Sprinkle some water to keep the jute bag wet & bury the kitchen waste in the straw layer use a different spot everyday.

Harvesting the Compost

After six to eight weeks the top layer would be decomposed and will look like brown teadust. When this happens, stop watering for 2-3 days & don't add any new waste. Remove the top layer upto a depth of 12-15 cms, and replace it with fresh layer of straw.

The harvested vermicompost is excellent plant food, just add a 3-5 cm deep layer on top of your flower pot or vegetable bed & mix it gently into topsoil; if you are transplanting seedlings, add a handful in every hole before planting them.


net cover to protect the earthworms from rats,cats, birds etc
double layer of soaked jute bags to keep the surface cool & moist.
30-35 cm deep layer of dry straw leaves etc in which small quantities of food waste etc are buried everyday
layer of green coconut shell, paper balls etc 15-20 cm
layer of silt + compost 3-5 cm
Pebble layers with 2-3 sheets of newspaper underneath
drainage holes at bottom 6-8

Chapter 2 Plant Propagation

Trees are almost like human being... Ramu was excited from last Sunday's lesson. This Sunday he also started enquiring about plant. "What is a seed, Nani? How come such a big tree come out of this small seed?" Ramu asked.

"Just like your father who has grown from a small child to a big man. He had to take milk,, fruits and vegetables everyday... and he became big. You also need healthy food to grow up! Yesterday, I told you that tree consumes special kind of food prepared in the leaves".

"Seeds do not look like the tree. But I look like my father."

"Your father was also like a small seed when he was in my womb, I fed him through my blood. Mother Trees don't have womb, they allow seeds to mature in the nature itself!"

"Why have you kept those seeds?" Ramu pointed out to the seeds Nani had collected all through the season.

"Well, I kept those seeds for **propagation** and you know propagation by seed is the most commonly known method of producing new plants."

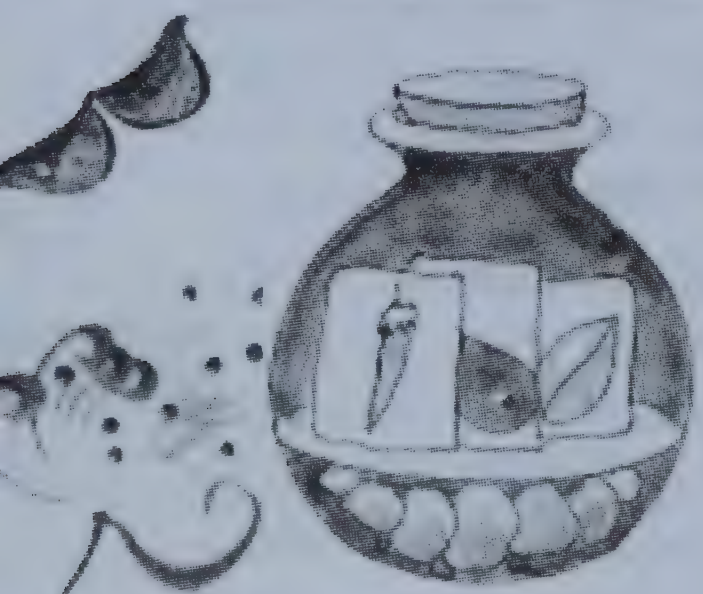
"Nani! Which seeds are better, the seeds collected at home or seeds purchased from the market? "

"Obviously, the collected ones, as the quality is ensured."

It's true that almost all kind of seeds are available in the market these days, but if we can produce seeds by ourselves then it saves money. It allows the gardener to maintain varieties that are not sold commercially. Many avid seed savers belong to groups that exchange seed through networks.

SEED COLLECTION

Collect mature seeds from healthy trees.



PROCESSING AND STORING

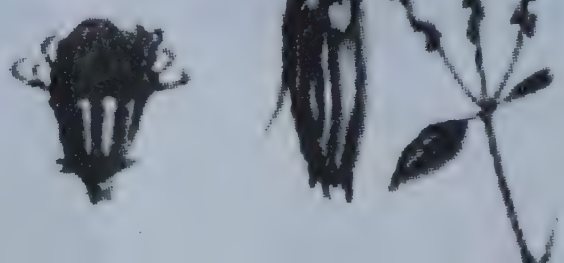
Remember to store seeds in dry, cold and dark places.
Store them in brown paper bags inside earthen pots or glass bottles. Put some absorbants inside and cover tightly.

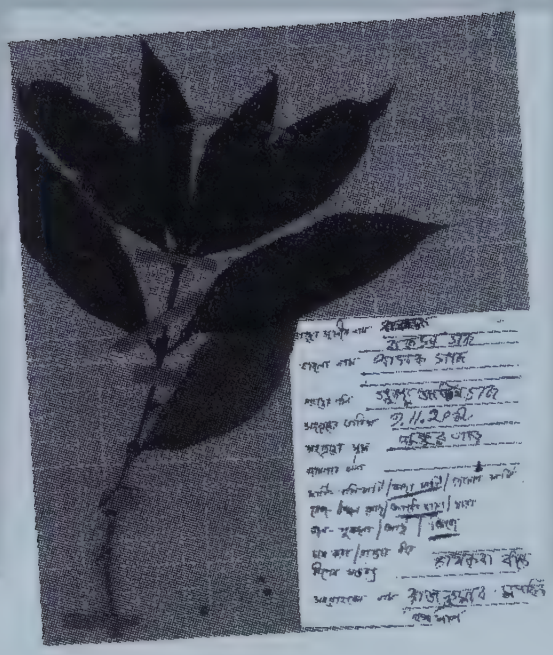
PRECAUTIONS:

Never dry seeds in strong sunlight.

- Dry your storing container properly.
- Sort spoiled / infected seeds before storing.
- Use neem oil in bottle for storing beans, pea or pulses.
- Mix clean ash for vegetable seeds.

How seeds propagates





RECORD KEEPING AND LABELING

Mention

- species (scientific or common name)
- habitat (where it grows)
- collection site
- collection day
- germination period
- collector

"I have seen that some seeds are covered with a very strong and hard coat. How do they germinate, Nani?" Ramu asked.

"Yes! We have to apply some techniques. Particularly hard seeds may be scarified."

Scarification involves breaking, scratching or softening the seed coat to allow moisture penetration. Two methods of scarification commonly used –

- weakening of seed coat with a file or hammer.
- placing seeds in hot water. (170-210°F). Alow to soak for 24 hours after cooling.

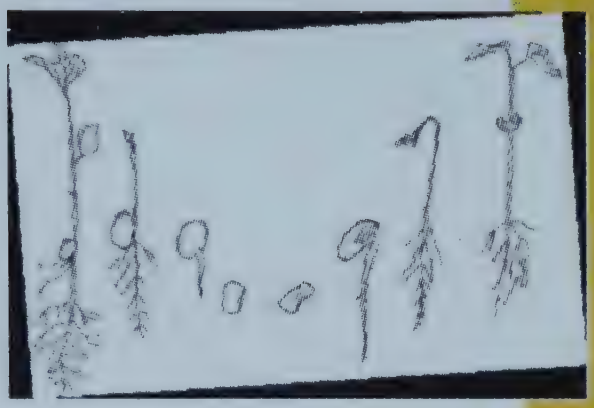
Do it yourself

Take seeds of different types and thickness (pumpkin, mustard, green gram etc). Sow them on the same date, under same condition. Oberve them and take notes.

- When do they germinate? Why one seed germinates later that the other?
- How do they germinate and condition of the seed after germination
- How leaves appear?
- Note the growth for 7 days.

Can you name?

- Some seeds need to be semi digested by birds before they germinate?
- Some seeds need 2-5 years to germinate?
- Human beings are unconciously responsible for spreading seeds, at times.
- Some seeds are liquid?



Keep thinking

- Why are seeds planted at different depth?
- What would happen if we planted the same type of seed at different depth?
- What type of soil mix is best for starting seeds?
- How do different types of seeds germinate?
- Why do roots grow down and

SOWING SEED

Fill the container to within 1/4 inch of the top of the container with moistened seed-starting medium like soil and compost mixture. After sowing seeds, keep the medium moist, not wet.

Sow very small seeds by sprinkling on top of the medium and pressing in. Use a fine mist of water to gently wash seed into the growing medium.

Sow medium-size and larger seed in rows 1 to 2 inches apart, and 1/8 to 1/4 inches deep.

If no depth is specified on the seed packet, use the general rule of planting the seed at a depth twice the diameter of the seed.

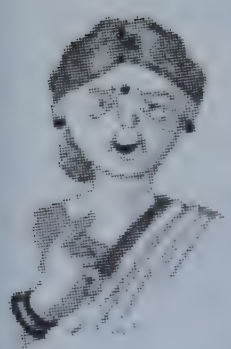
"But Nani, trees grow from stems also! Don't they?" Ramu asked.

"Yes. We do not get seeds from all plants, so we have to adopt different methods of plant propagation. Not only from stems, but from almost everything! Naturally from leaves, roots, stems and seeds. Artificialy we make it from stems through cutting and budding."

Take an example Of T budding or Shield budding, it is a special grafting technique in which the scion piece is reduced to a single bud. Otherwise they will dry out.

Chapter 3 Designing a Kitchen Garden

Daddy brings a bagful of vegetables every Sunday. But this is a special Sunday. Nani asked daddy not to buy vegetables. Everything will come from her garden. Ramu was excited like anything while plucking cucumber, picking up radish and spinach!!



Nani said proudly – "It is the only option to get fresh, poison free, nutritious vegetables, fruits and tubers, to combat daily ailments. I also have flowers for my puja."

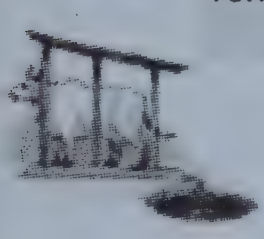
"Yes Ma, I must agree, these vegetables taste much better than those from the market"- daddy agreed.

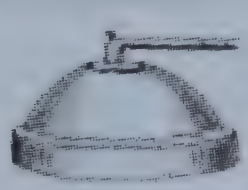
"Not only that, this is the best way to recycle and reuse used kitchen water and other kitchen wastes.."

"You can also reduce your expences" – Ma added.

"And it is nice to see butterfly dancing on the flowers from the window" – Ramu quipped.

Besides kitchen waste, one can use waste from cow shade etc. for production. Birds & animals can be fed plant wastes, their excreta can be used to make biogas, and the slurry produced can be used as fish feed or earthworm feed and remaining part can be used as organic manure. In a kitchen garden; kitchen wastes, wood ashes, animal and bird manures and urine, rotten roofing material, wastewater etc. are always possible to recycle. These kind of multi-use elements/products & multi step-processes help to increase the energy efficiency of a production system.





"Now tell me Ramu what do you need for a kitchen garden?" – Daddy asked.

"First thing is Sunlight Daddy. Because without that plant cannot make food. Then water is also important, and soil"

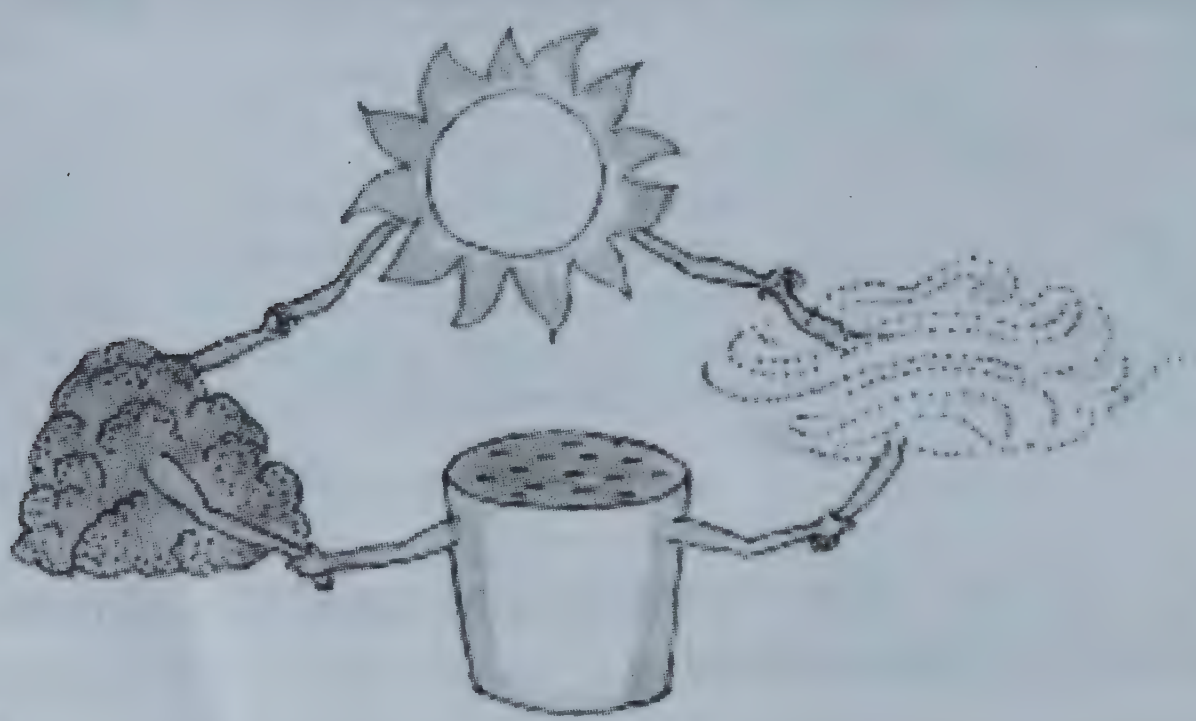
Few of them need strong sunlight, some like shade. So the gardener needs to map sunlight zone properly to plan the garden keeping in mind the seasonal changes.

Plant needs water, but they don't like excess of water. Some places in India are draught prone. So this issue needs special attention. The gardener should try to map –

- How much waste water is produced in the kitchen?
- The rainy season and the possible amount of rainwater stored
- Slope of the garden
- Flowing path of water during rainy season, especially in draught prone area, to maintain certain moisture level in the soil and to prevent evaporation loss, one must think about using dry leaves, straw and creepers with big leaves for mulching. Mulching helps soil to regain its water holding capacity. Pitcher and drip irrigation could be a very useful technique.

The most important but neglected component of farming activities is soil. Usually soil is referred to as a living substance, as several species of microorganisms are working together to keep the soil healthy and fertile.

Ramu forgot about Air. It has a very important role to play in ecology, in soil erosion, in controlling evaporation. If we anticipate properly, introduction of bushy plants can check the air and can also provide a constant supply fuel wood round the year.



"To get maximum utilization of a kitchen garden, there should be at least six types of crops – Leafy Vegetables, Fruits, Legumes, Roots and Tubers, Spices and Medicinal herbs." - Nani added.

Why mixing crops?

Do you know that if you have strong smelling plants like, ginger, onion, basil or marigold in your garden it could act as pest repellant. Leguminous plant can offer nitrogenous input from nodules of the root.

While planning and selecting species we need to consider

- Some plants are seasonal, some are perennials
- Some like shades, others prefer sun light
- Some need water, while others can tolerate the scarcity of it
- Some are short rooted, while others are deep rooted.

Do it yourself

Make a season wise list of the above mentioned plants which you have seen.

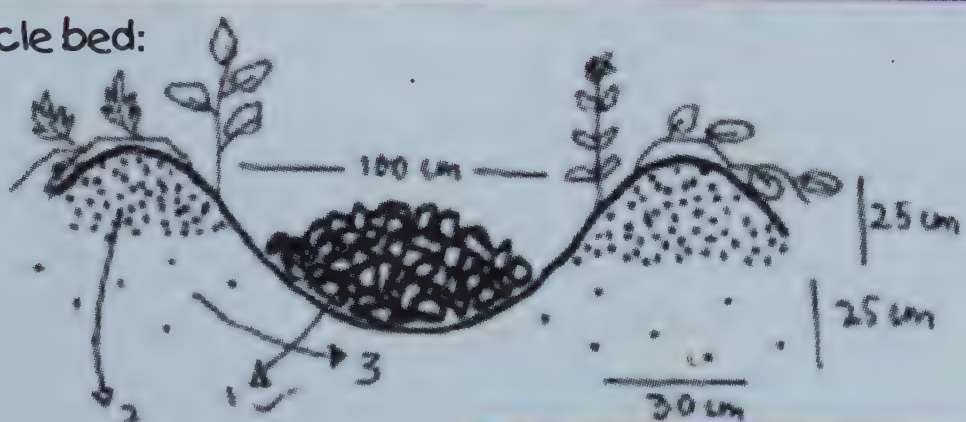
"So, Happy Gardening, Ramu!" Daddy said.

Do you Know these gardening tools?

Some Tips

Mulching: Mulching is to cover the soil surface with 15cm or more of organic material such as dry green grass, tree leaves etc to protect soil. It can add nutrients to soil after it gets decomposed.

Circle bed:

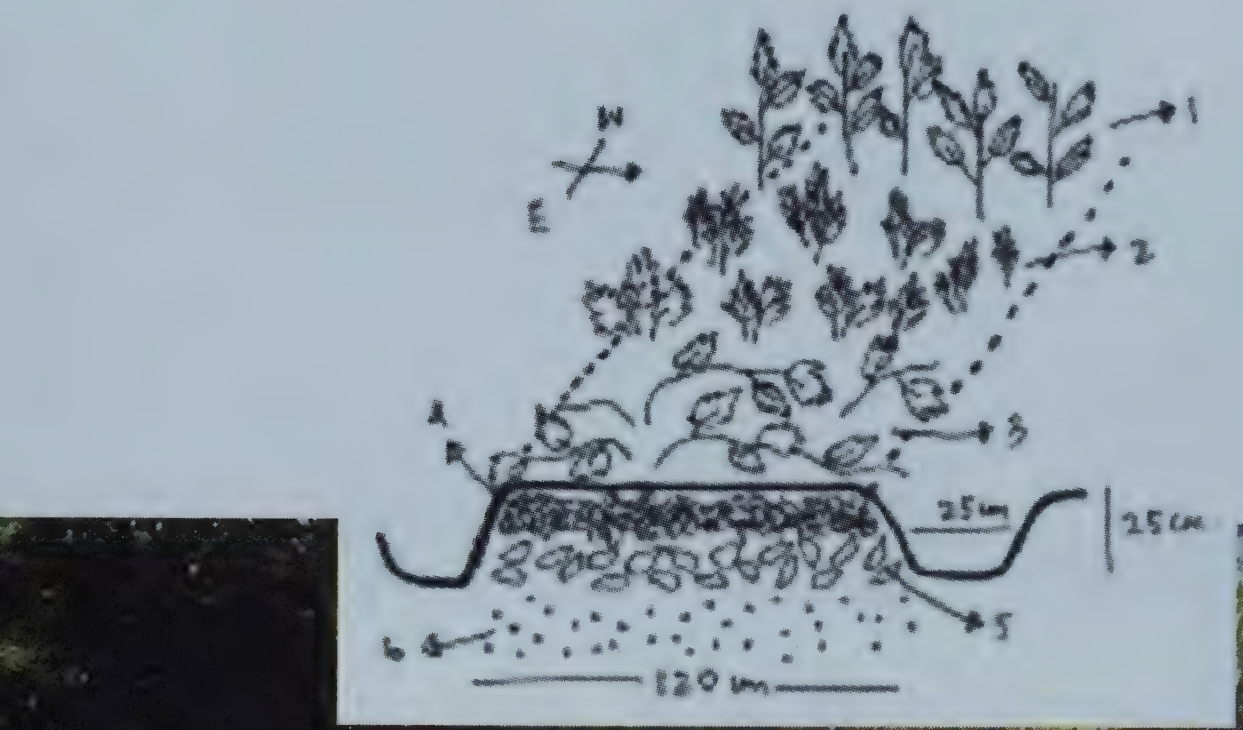


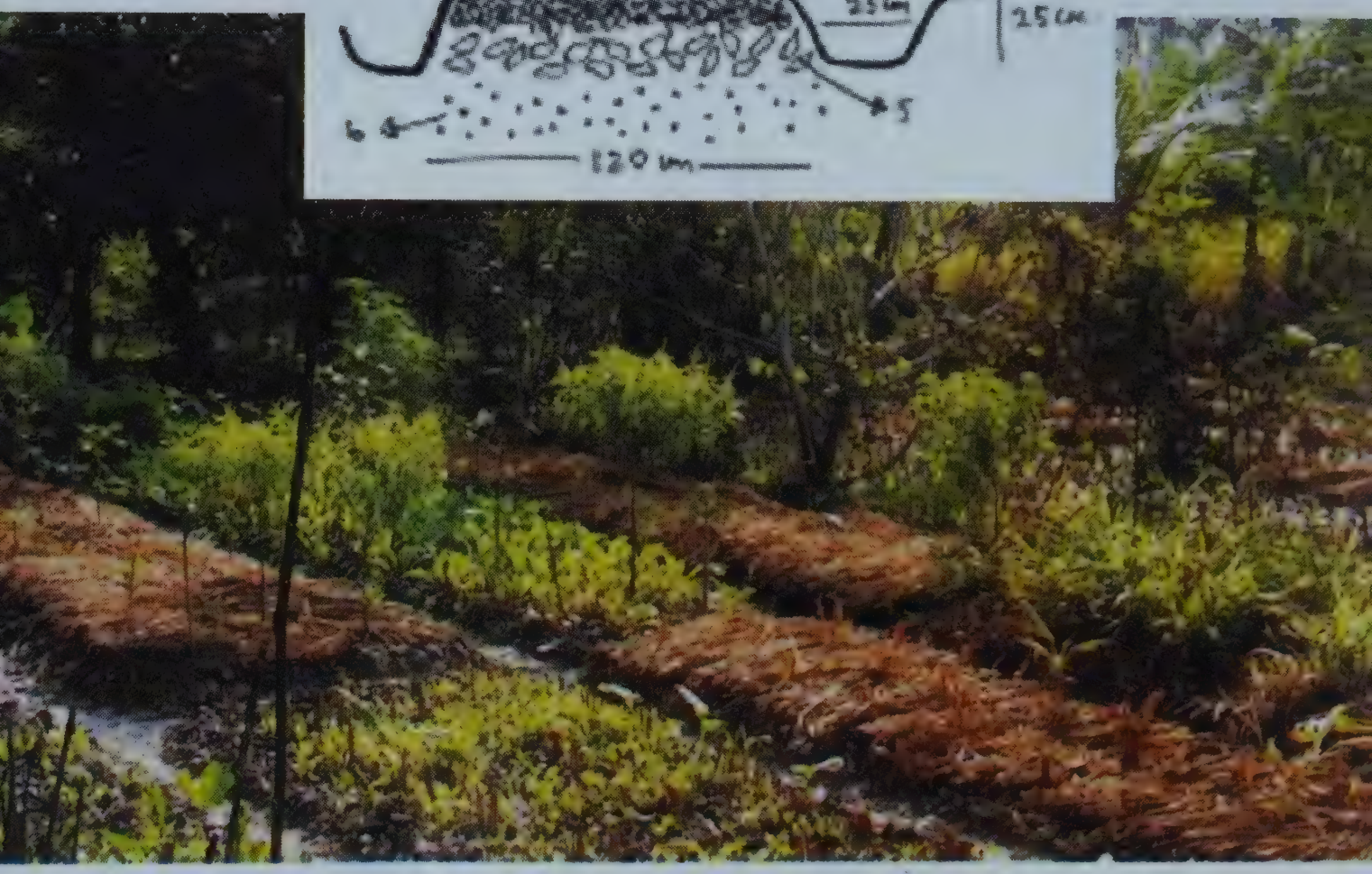
1. Organic waste and water
2. Raised portion. Plants which need more water can be planted on inner side.

This helps getting various types of vegetables with small amount of water.

Raised bed: This bed is useful for clayey soil and waterlogged area. Here ridges and drains should come in sequence so that drains can be used for irrigation, drainage and as means to reach and maintaining the beds. Beds should be laid in east-west direction to get maximum sunlight.

1. Tall vegetables
2. Short height vegetable/leafy vegetables
3. Creepers
4. Mixture compost and dugged up soil
5. Layers of dry leaf and straw (4~5 cm)
6. Loose soil





Living Fence

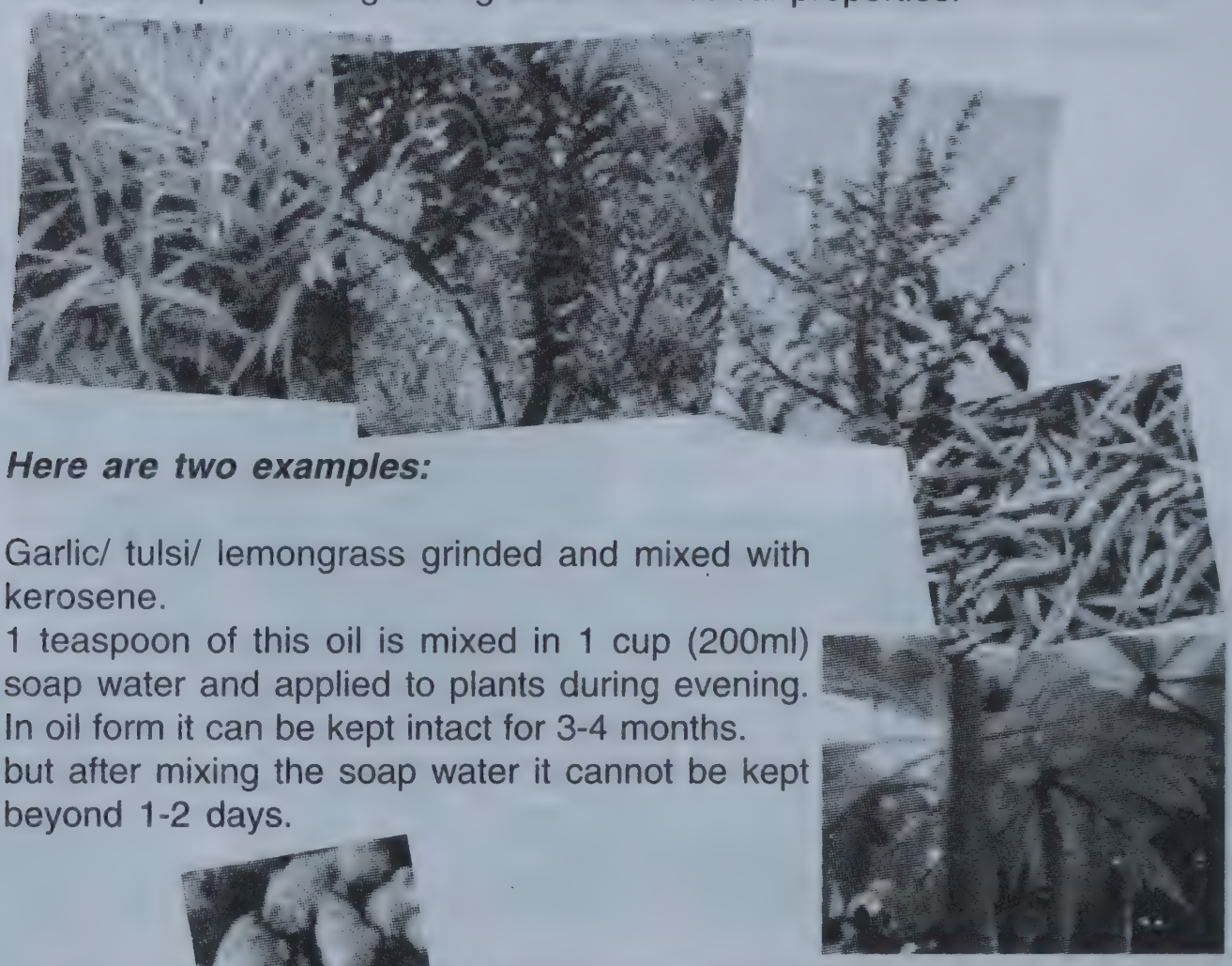
1. Trees which are pollard able (cut in upper portion): Indian Coal Tree, Drumstick, Neem, Sesban
2. Trees which are coppicable (cut in lower portion): Gliricida, Subabul,Kanchan, minjiri
3. Plants having thorny leaves: Pinapple, Alloevera, Ageav
4. Bushy short height plants: Karaunda, vasak, Vitex negundo, hibiscus
5. Creepers: sword bean/Jack bean, greater yam

As space in the kitchen garden is very limited we need to use it effectively. So like the ground, we need to think about the **vertical space** also.

Do it yourself: Plant Extracts as Biopesticides

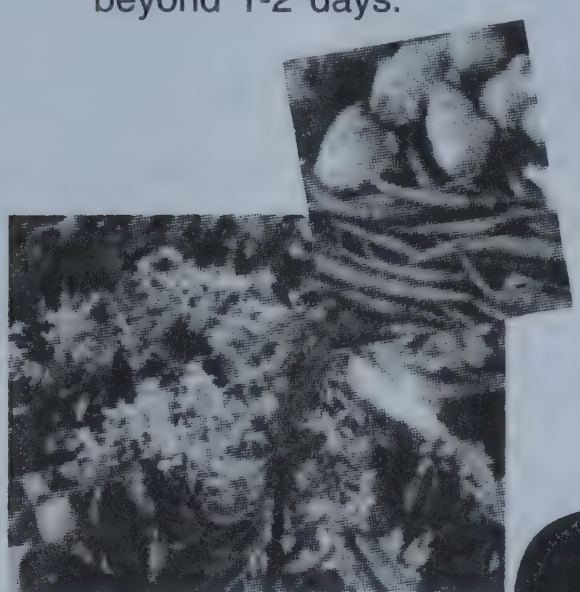
Generally, biopesticides are produced from trees-

1. Having bitter leaves
2. Secreting milky white liquid or gum (often poisonous) from broken ends of branches or leaves.
3. Leaves possessing strong smell or medical properties.



Here are two examples:

Garlic/ tulsi/ lemongrass grinded and mixed with kerosene.
1 teaspoon of this oil is mixed in 1 cup (200ml) soap water and applied to plants during evening.
In oil form it can be kept intact for 3-4 months.
but after mixing the soap water it cannot be kept beyond 1-2 days.



Leaves of papaya, neem, etc. are grinded and mixed with equal quantity of water.
At evening it is sprinkled on plants after mixing with 6/8 times water.
It cannot be kept beyond 5-7 days and should be prepared fresh as per requirement.

Keep thinking

Why we should use biopest repellant rather than chemical pesticides.

In spring, the small garden looks splendid in seasonal flowers, bright butterflies and buzzing bees. Ramu learnt from Nani, how the relation between flowers and these insects are mutually beneficial.

Ramu read in a book that plants also eat animals!

Keep thinking

why do you think the insects depend on plamnts and vice versa.

"Are there plants that eat animals?" - Ramu asked Nani.

"True, but they can not eat elephants! There are insect eating plants in nature."

The Venus flytrap is an oft quoted example. A member of the pitcher plant family, which has a particular preference for termites, and eats thousand of them at one go.

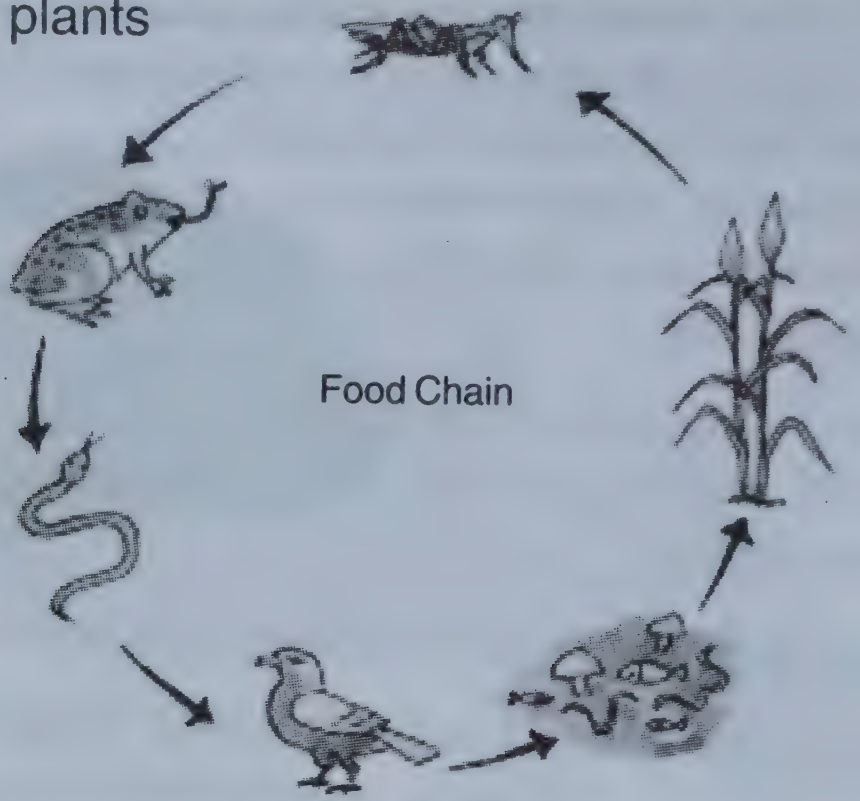
"Well! Why don't insect attack neem tree?"

"Neem is one example of plants which release chemicals that can stun insects. They synthesize and store a chemical called azadirachtin. Using this, we can make biopestrepellent out of neem"

Find out

	as medicine	as pest repellant	as cosmetics / daily use
leaf fruit seeds bark			

Directly or indirectly all consumers derive their nourishment from plants



This is an ecosystem of a pond. Can you identify food chains ?

Do it yourself

What types of plants, insects, birds you can see in your kitchen garden ? What is their relation ? Can you identify food chains ?

Pollination: The transfer of pollen from the male **anther** to the female **stigma of a flowering plant.** The transfer may occur in the same plant (having bisexual flowers) or between two different plants (with unisexual flowers). Pollination is done by agents like wind, water and animals for the transfer of pollen.

Why do animals pollinate plants?

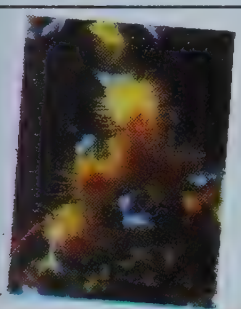
They get a REWARD: food! In exchange for moving their pollen to another flower

- **Nectar** – a sugary solution produced in special flower glands, Nectar meets energy requirements of the pollinators like birds and bees.
- **Pollen** – is high in protein, some bees and beetles eat it.

What do the plants do to get the pollinator's attention?

Plants advertise their pollen and nectar rewards with

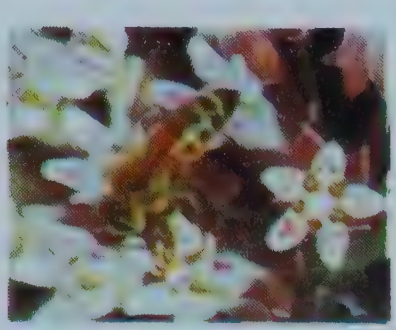
- Colors – bees see blue, yellow, ultra violet; while birds see red. Bats don't see well, so flowers are white.
- Nectar or honey guides – a visual guide for pollinators to locate the reward (pansy flower)



Vegetables and Pollination

Fruits or vegetables which develop from well pollinated flowers are well structured, heavy, and tasty. Fruits which are not well pollinated or partly pollinated become rugged and less tasty or sweet.

Most plants of cucurbitaceous family (Bottle gourd, Ash gourd, Cucumber, Water melon, Pumpkin, Ridged gourd, Bitter gourd etc.) do not have Complete flower. Therefore pollination is very important for them. Tomato, birnjal, lady's finger have complete flowers and they fruit without the help of bees or other pollinators, but formation of tasty and well structured fruit is only possible through pollination. The wind does the pollination for the crops of graminae family (rice, wheat, meals etc.)



Some Pollinators

Bees

The most sophisticated relationships between plants and insects are generally those involving bees. Bees collect pollen and nectar not only for themselves but also to feed their young. Bees have special hairs that are arranged to form pollen 'baskets' on their hind legs and the underside of their abdomen. Bees are ideal pollinators because they visit many flowers while carrying lots of pollen, before returning to their nest. So the chance that a bee will transfer the pollen between flowers of the same species is very high.

Butterflies and moths

- Guided by sight and smell
- Butterflies can see red and orange flowers
- Usually shaped as a long tube because of insect's proboscis – to get nectar
- Moth-pollinated flowers are usually white or pale, with sweet, strong odor – for night Pollination.

Flies and beetles

- Flies like flowers that smell like dung or rotten Meat.
- Beetles pollinate flowers that are dull in color, but have very strong odor

Mammals: bats and mice

- Bats pollinate at night, so flowers are white
- Mouse-pollinated flowers are usually inconspicuous They open at night

"But Nani, there are other insects in soil also…they are so ugly looking…eeks!!" Ramu made a face.

"They might be ugly looking my boy, but they help us to survive!" - Nani said.

" Help us! How?"

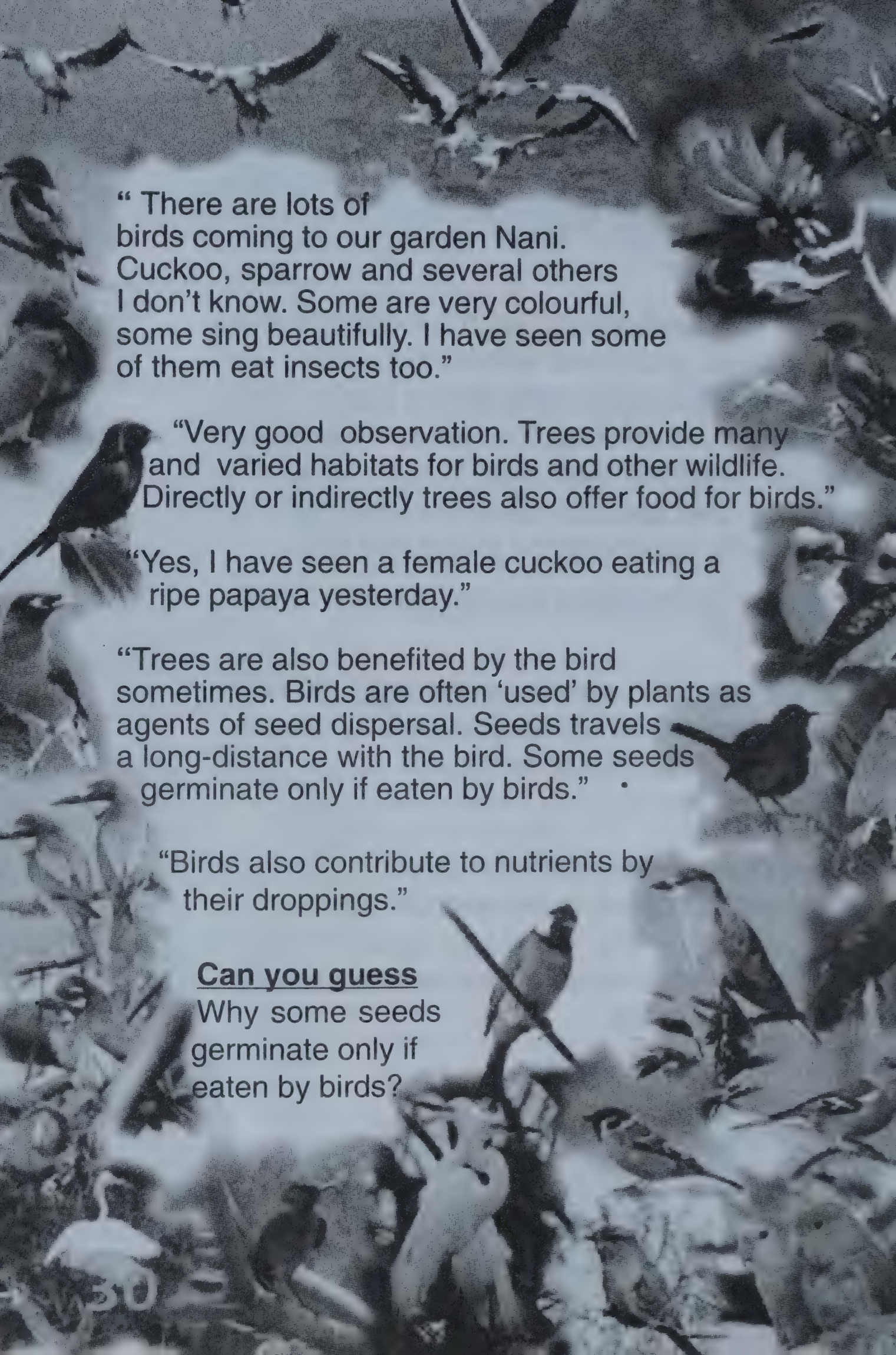
"Certain **decomposers**, such as dung beetles and sow bugs, in cahoots with fungi, bacteria, and other microorganisms, make life on Earth livable. They make the soil living. They feed on once-living materials, breaking them into simpler molecules that can be used again as nutrients for plants. When we eat plants, we should be thankful to them."

"Are they in trouble when we apply **chemical pest repellents?**"

"Yes, my dear. You are absolutely right. Some insects are harmfull for some other particular inscets. We can try a tit for tat method."

" What is that? "

"Insect **predators** (such as ladybugs, praying mantis, and lacewings) and **parasites** (such as certain species of tiny wasps) are garden dwellers typically referred to as beneficial insects, since they aim at garden pests."



" There are lots of
birds coming to our garden Nani.
Cuckoo, sparrow and several others
I don't know. Some are very colourful,
some sing beautifully. I have seen some
of them eat insects too."

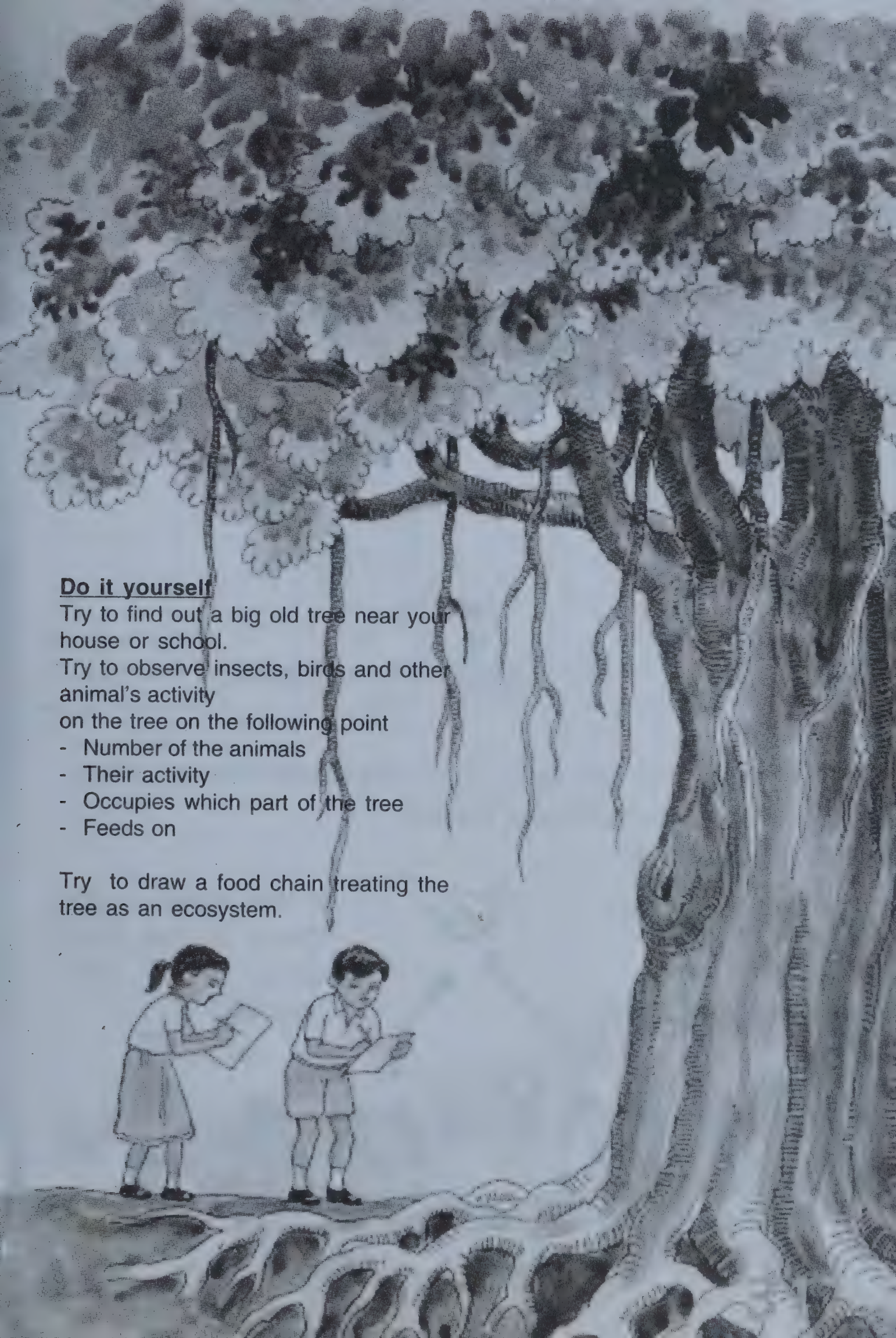
"Very good observation. Trees provide many and varied habitats for birds and other wildlife. Directly or indirectly trees also offer food for birds."

"Yes, I have seen a female cuckoo eating a ripe papaya yesterday."

"Trees are also benefited by the bird sometimes. Birds are often 'used' by plants as agents of seed dispersal. Seeds travels a long-distance with the bird. Some seeds germinate only if eaten by birds."

"Birds also contribute to nutrients by their droppings."

Can you guess
Why some seeds germinate only if eaten by birds?



Do it yourself

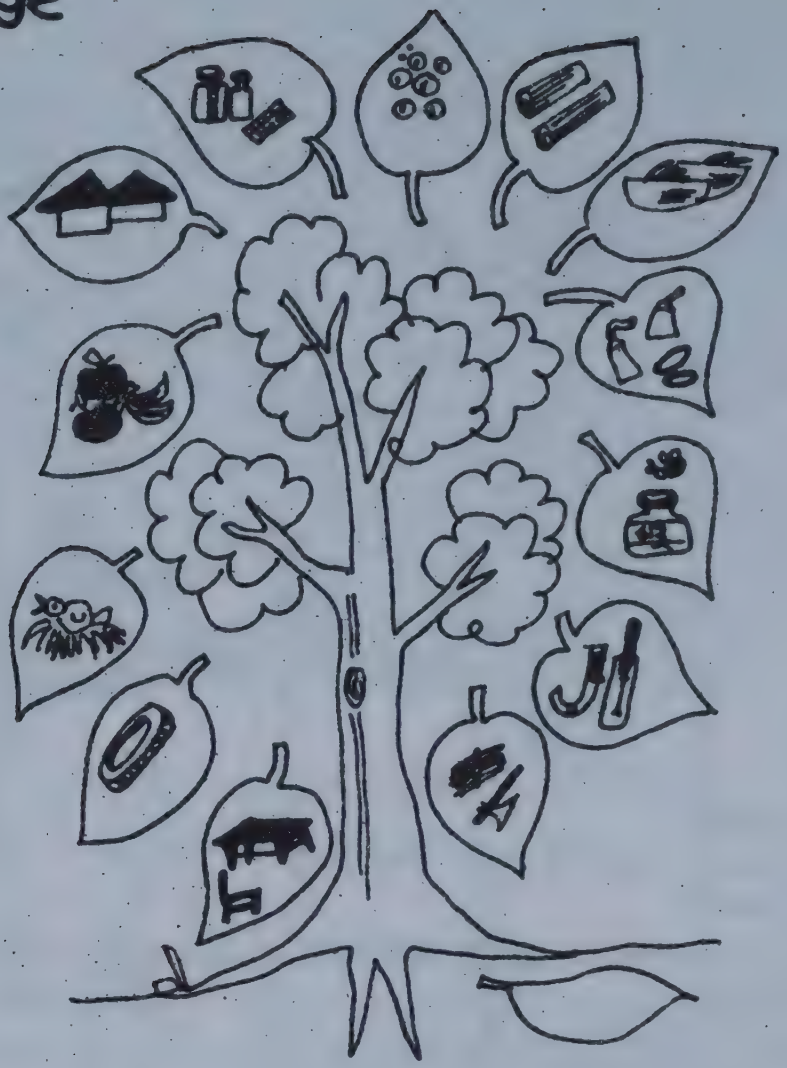
Try to find out a big old tree near your house or school.

Try to observe insects, birds and other animal's activity
on the tree on the following point

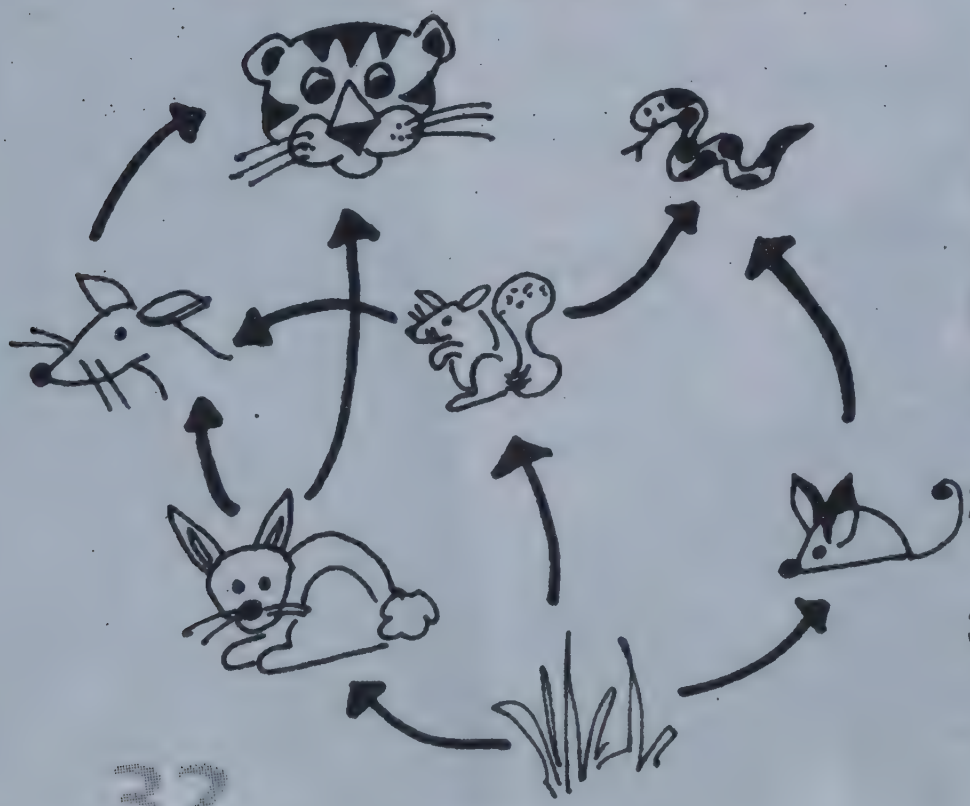
- Number of the animals
- Their activity
- Occupies which part of the tree
- Feeds on

Try to draw a food chain treating the tree as an ecosystem.

Activity Page



Make a 10 line write up on the above drawing after discussion with your friends.



If the jackal is not there in the food web, what will happen ?

1. _____

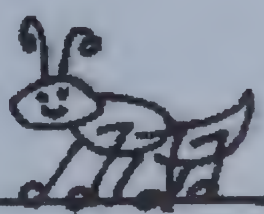
2. _____

3. _____

Plan your kitchen garden

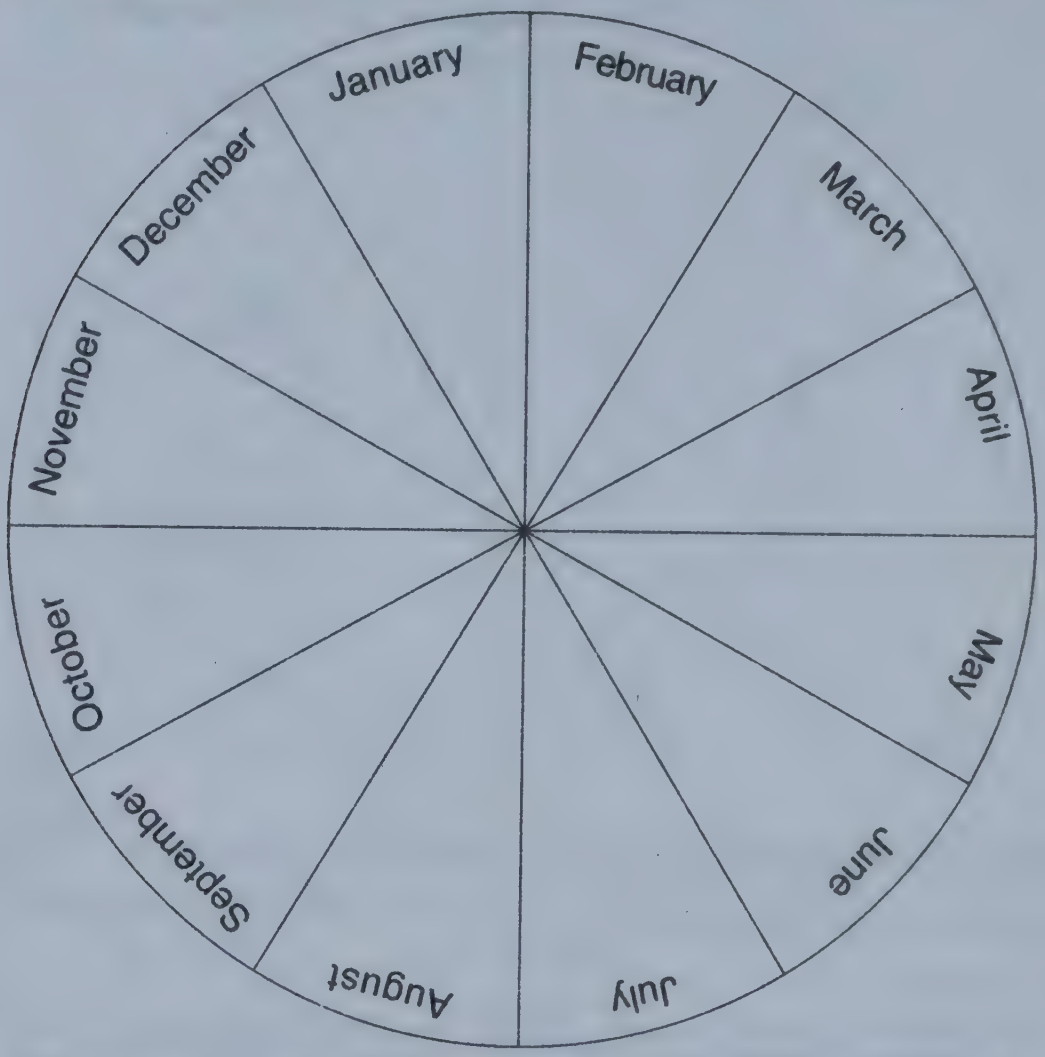
Season	Plants	Use	How to get seeds / seedlings	Time of Plantation	Care Required

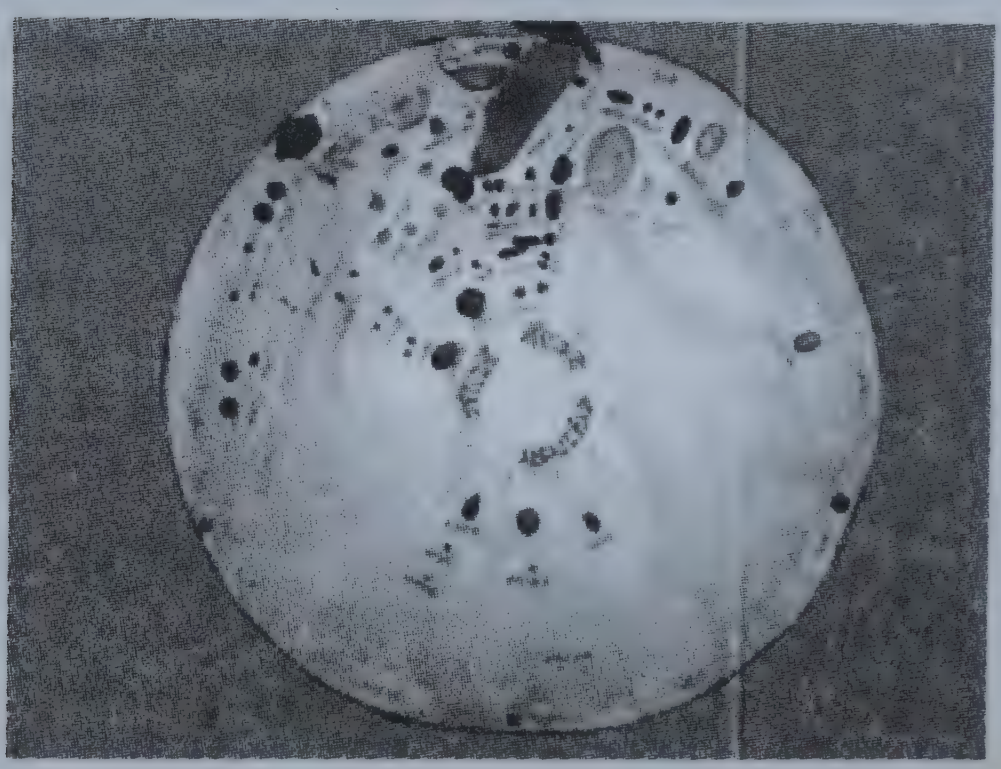
Observe insects in your kitchen garden

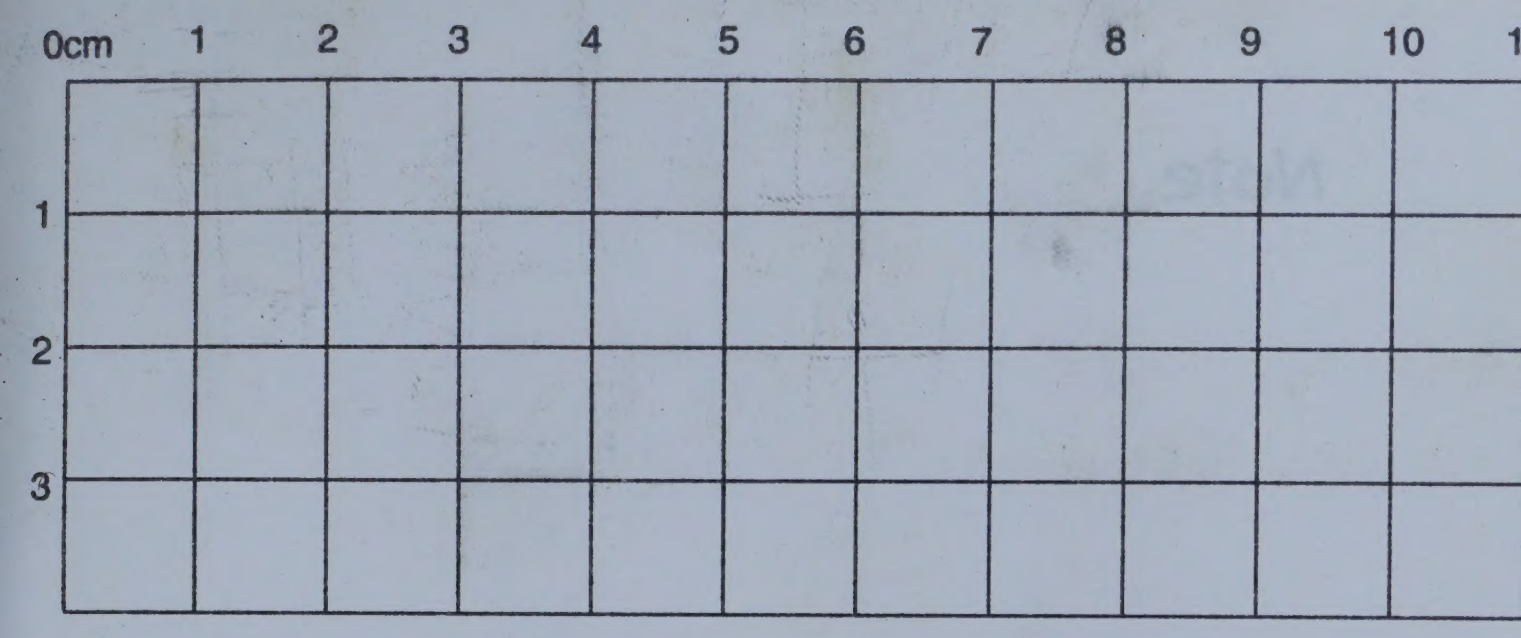


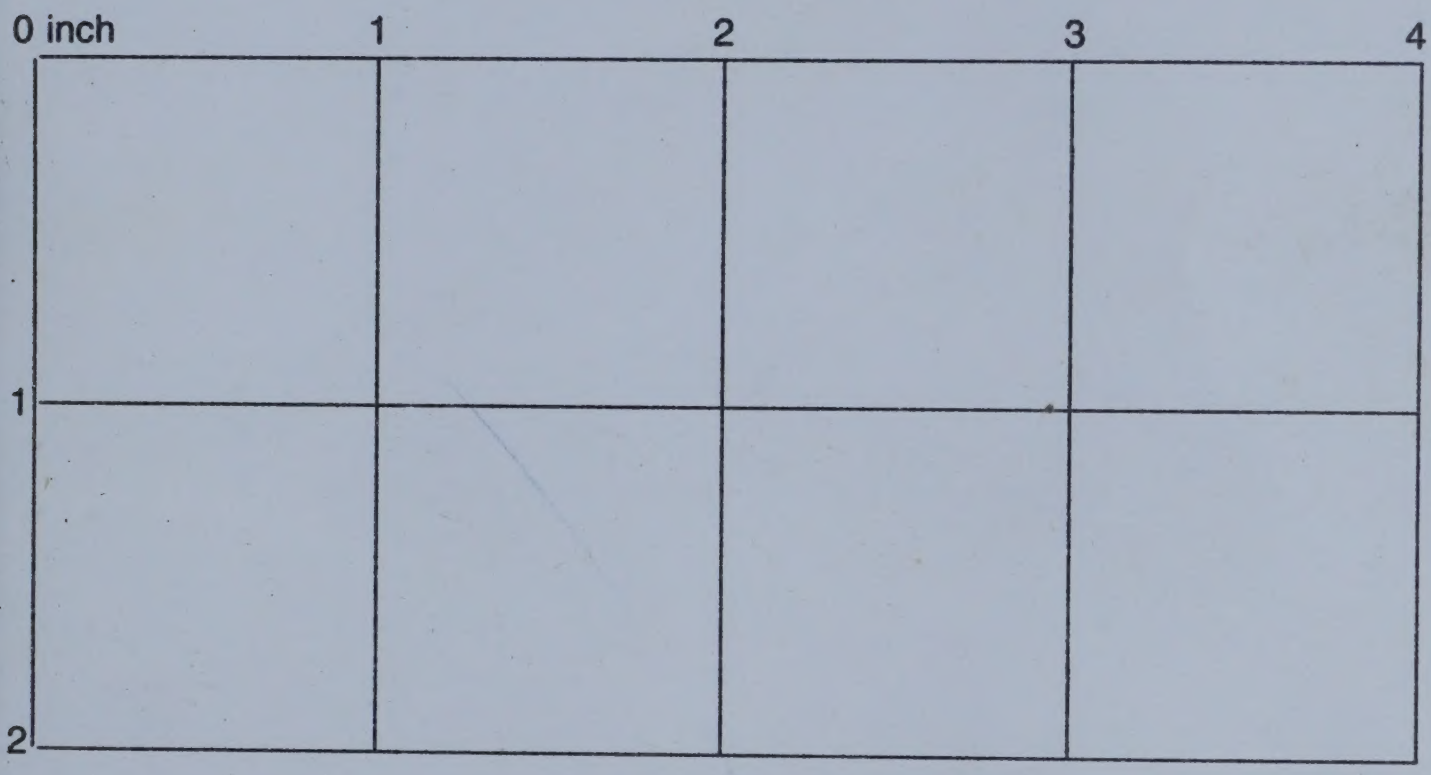
Insects	Where	What it was doing	Friend or foe	Relation with the plant

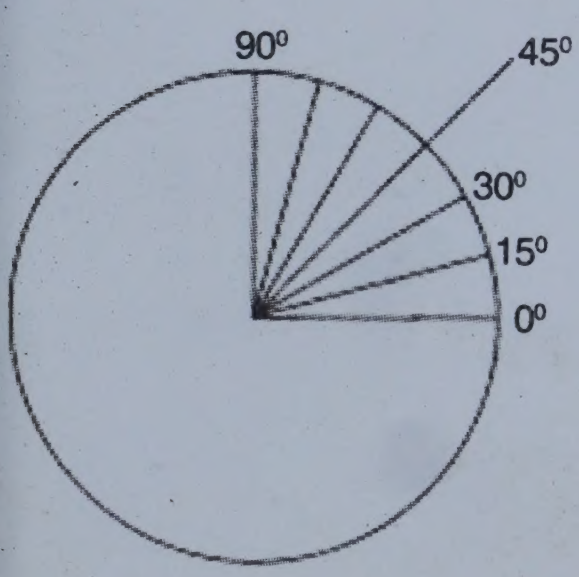
Make a seed calendar with the seeds collected from your garden

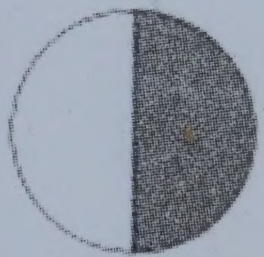




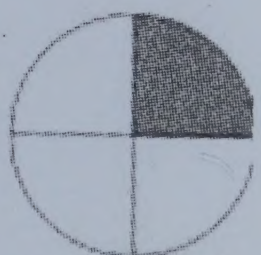








½ or 50%



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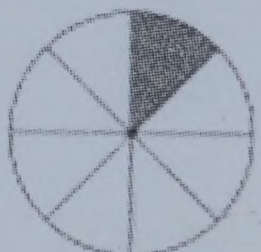
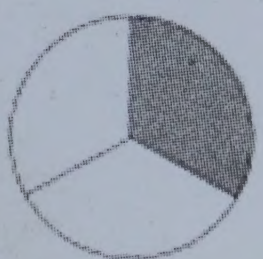
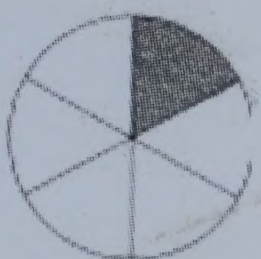


$^1/_8$ or 25%



$^1/_3$ or 33.33%



$^1/_6$ or 16.66%

$^1/_{12}$ or 8.33%

Note

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